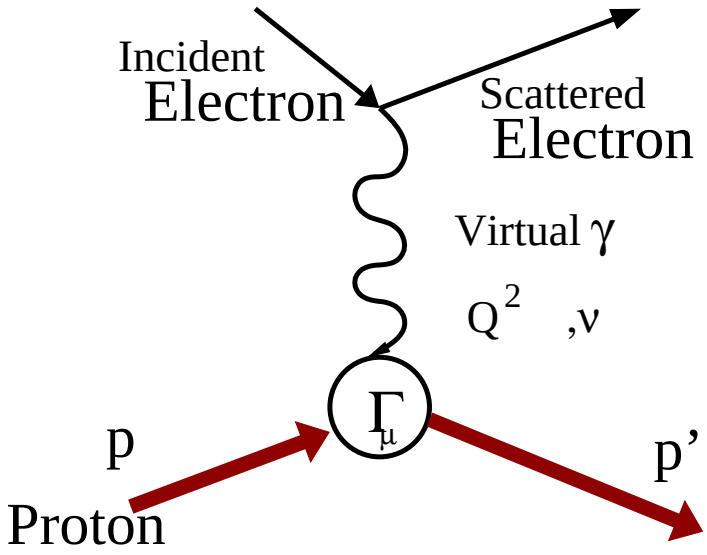
Recent and future measurements of nucleon form factors

Mark K. Jones, Jefferson Lab

2007 Hall C Summer Workshop

Elastic Electron-Nucleon Scattering



Nucleon vertex:

$$\Gamma_\mu(p',p) = \underbrace{F_1(Q^2)}_{Dirac}\gamma_\mu + \frac{i\kappa_p}{2M_p}\underbrace{F_2(Q^2)}_{Pauli}\sigma_{\mu\nu}q^\nu$$

$$G_E(Q^2) = F_1(Q^2) - \kappa_N \tau F_2(Q^2)$$

$$G_M(Q^2) = F_1(Q^2) + \kappa_N F_2(Q^2), \tau = \frac{Q^2}{4M_N^2}$$

At $Q^2 = 0$ $\quad G_{Mp} = 2.79 \quad G_{Mn} = -1.91$

$$G_{Ep} = 1 \qquad G_{En} = 0$$

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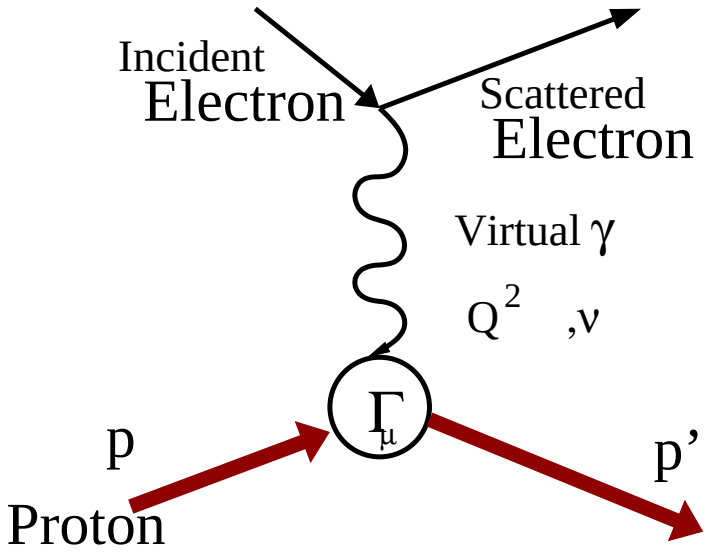

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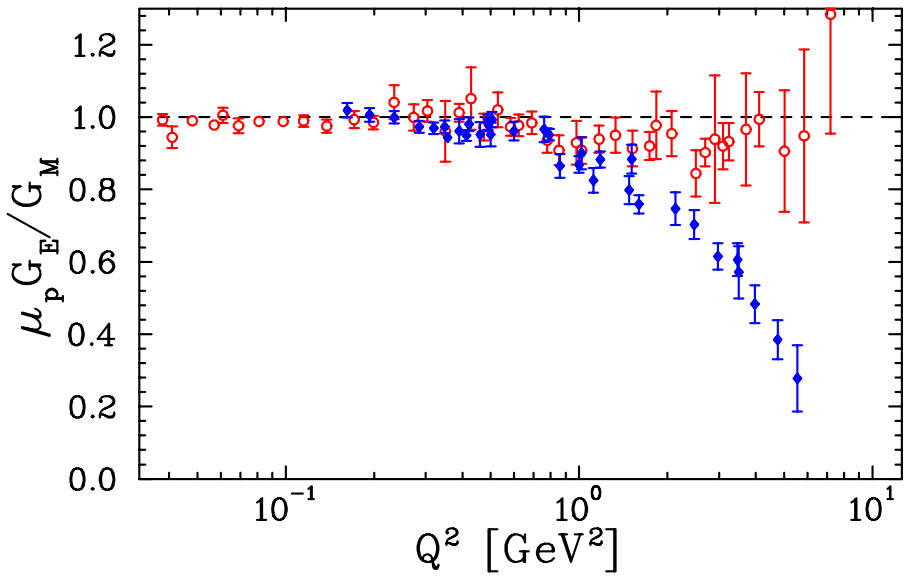
$\qquad\qquad\quad G_{Ep} = 1 \qquad G_{En} = 0$

- Measure cross section $\sigma \propto \frac{\epsilon}{\tau}G_E^2 + G_M^2$
- Measure recoil polarization in $p(\vec{e}, e'\vec{p})$

$$\frac{G_E}{G_M} = -\frac{P_T}{P_L}\frac{(E_e+E_{e'})}{2M}\tan(\frac{\theta}{2})$$

Discrepancy between two methods

- G_E/G_M extracted from cross sections and polarization transfer differ.



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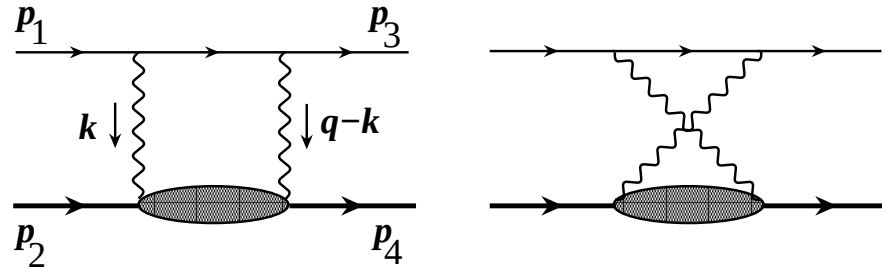
- G_E/G_M extracted from cross sections and polarization transfer differ.
- Most likely explanation is missing two-photon exchange (TPE) amplitude in extracting G_E/G_M from cross sections



Difficult to model intermediate nucleon states

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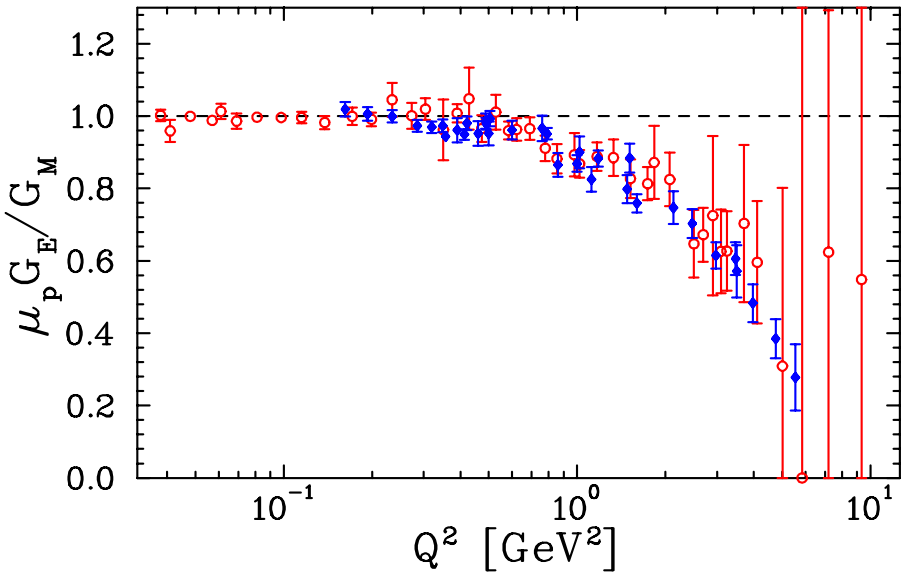
- New paper by J. Arrington, W. Melnitchouk, J. A. Tjon nucl-ex/0702002



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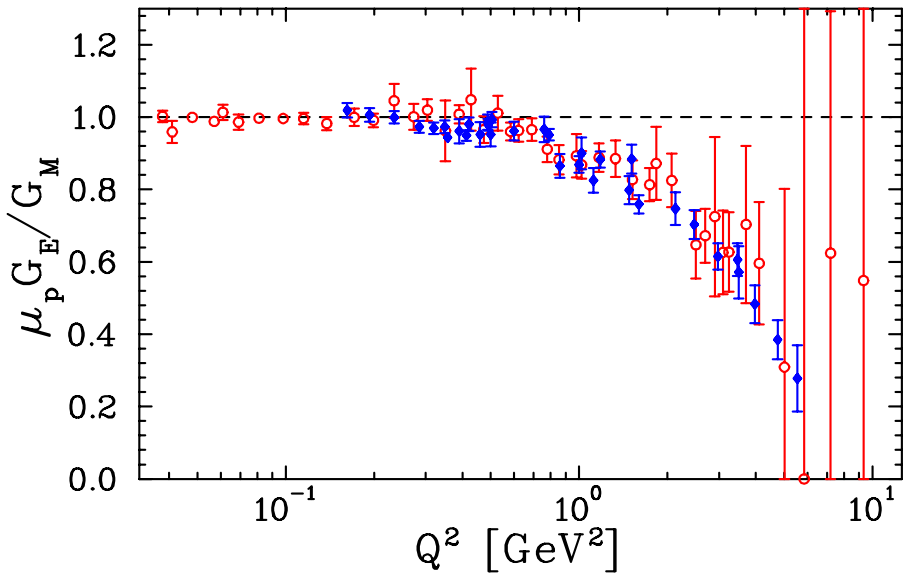
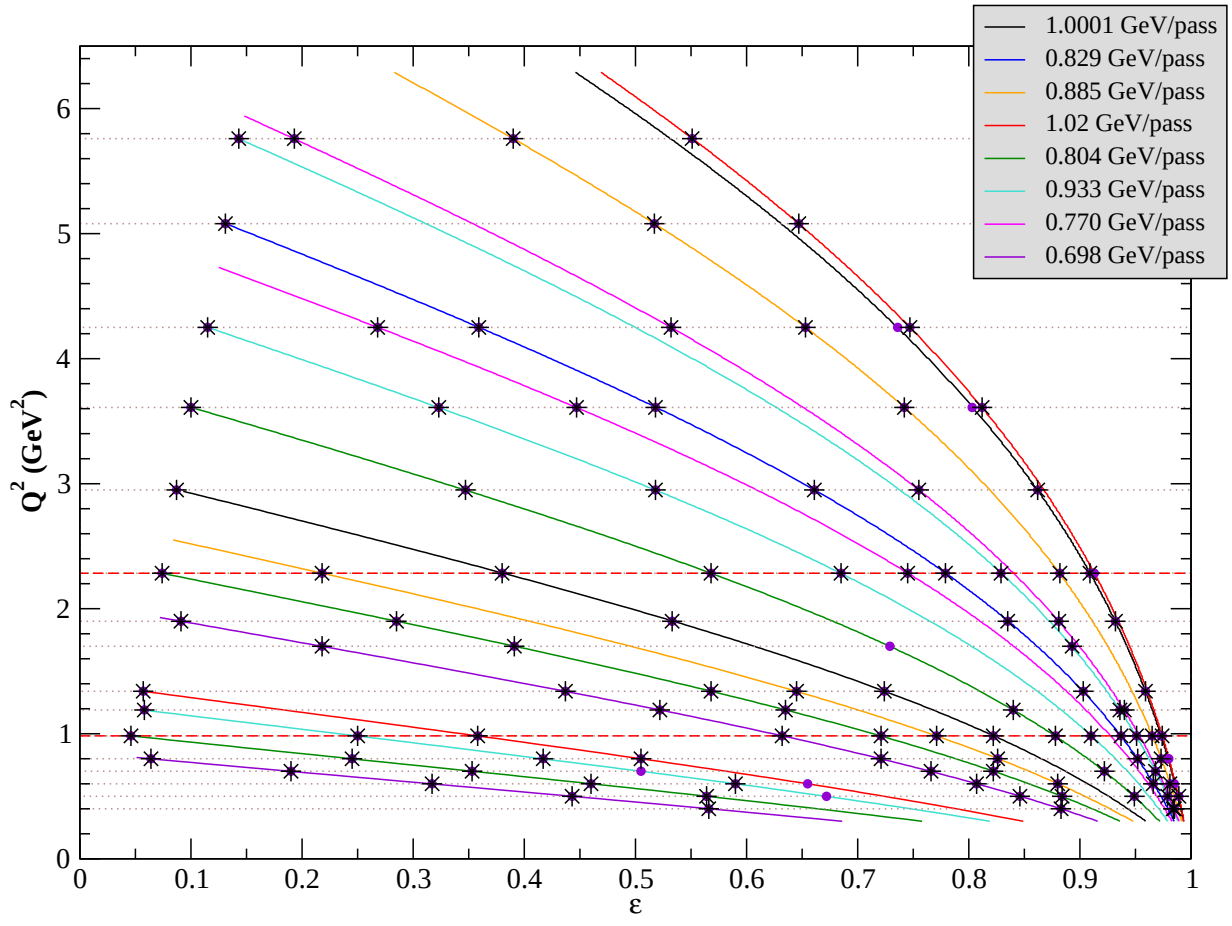
- New paper by J. Arrington, W. Melnitchouk, J. A. Tjon nucl-ex/0702002
- One clear signature of TPE is to measure ϵ-dependence of ratio of e^-p/e^+p elastic cross section in Hall B (*A. Afanasev, J. Arrington, W. Brooks, K. Joo, L. Weinstein, E-04-116*)

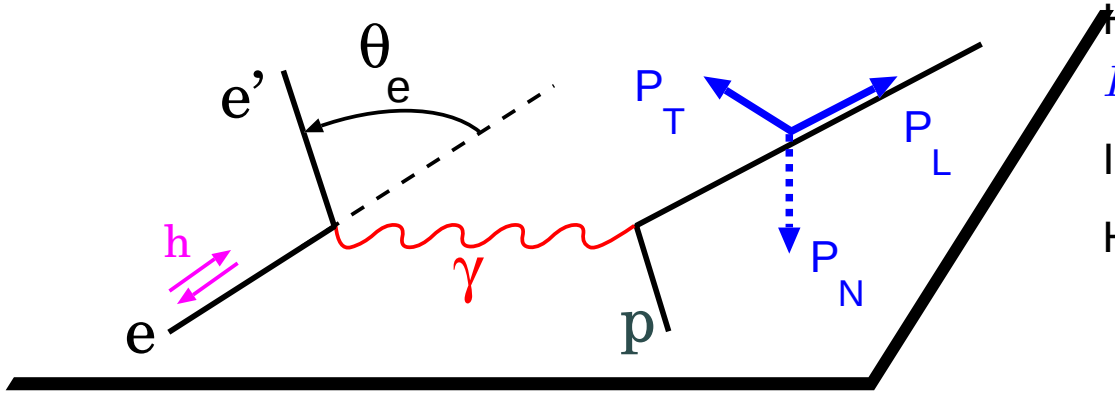


TPE effects in ep cross section

- Just completed Hall C experiment measured over $0.4 < Q^2 < 6\text{GeV}^2$ and $0.05 < \epsilon < 1$
- Detect elastically scattered proton in HMS
- Constrain models of TPE
  - non-linearity of $\sigma(\epsilon, \text{fixed } Q^2)$.
  - Combine with polarization data



Spin Transfer Reaction $^1\mathbf{H}(\vec{e}, e'\,\vec{p})$



Helicity dependent : P_N,P_T,P_L

$P_N = 0$ for elastic

In 1γ approx.

Helicity independent $P_N = 0$

- Need large solid angle device

  Large calorimeter (1.2x2.4m area) contructed from lead glass contributed by Protvino and Yerevan

- Proton spin measured by second scattering in polarimeter

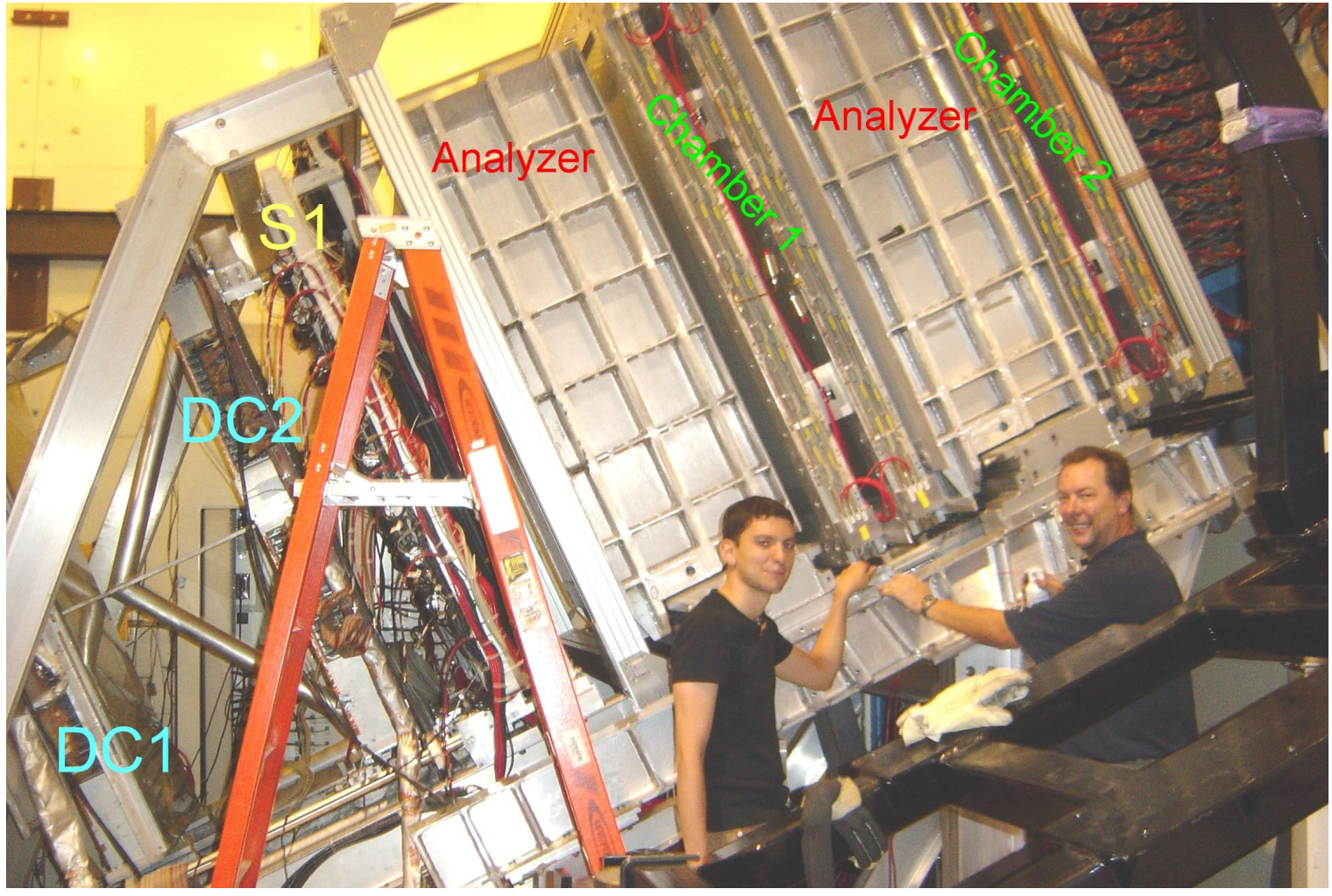
  Install FPP in HMS

BigCal in Hall, busy cabling

Thanks to: Albert Shahinyan, Samvel Mayilyan, Juan Cornejo, Omar Moreno, Amber Marsh, Eric Jensen, Boswyck Offord, Roman Pomatsalyuk, Yuri Melnik, Yuri Goncharenko

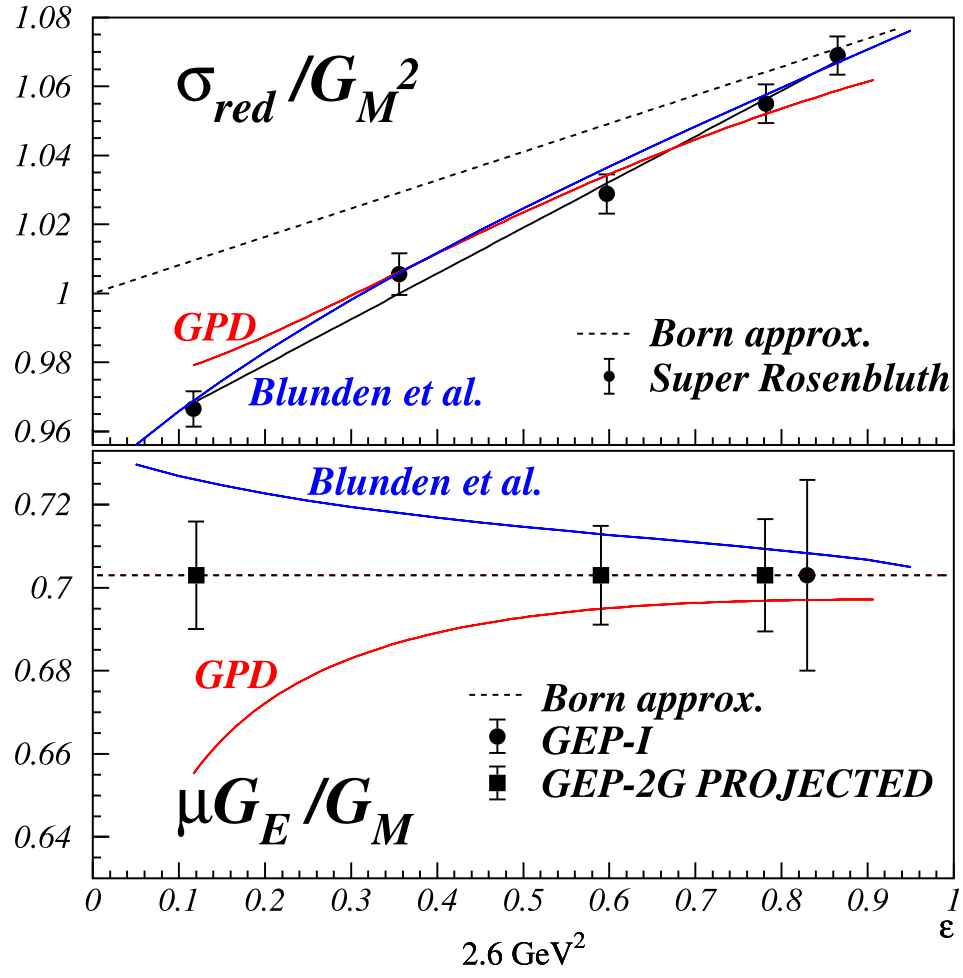
Grad students: Andrew Puckett, Medhi Meziane, Wei Luo

Fpp in HMS



TPE effects in recoil polarization

- Measure ϵ-dependence of $\frac{G_{Ep}}{G_{Mp}}$ extracted from recoil polarization method
- Experiment will run this fall 2007.



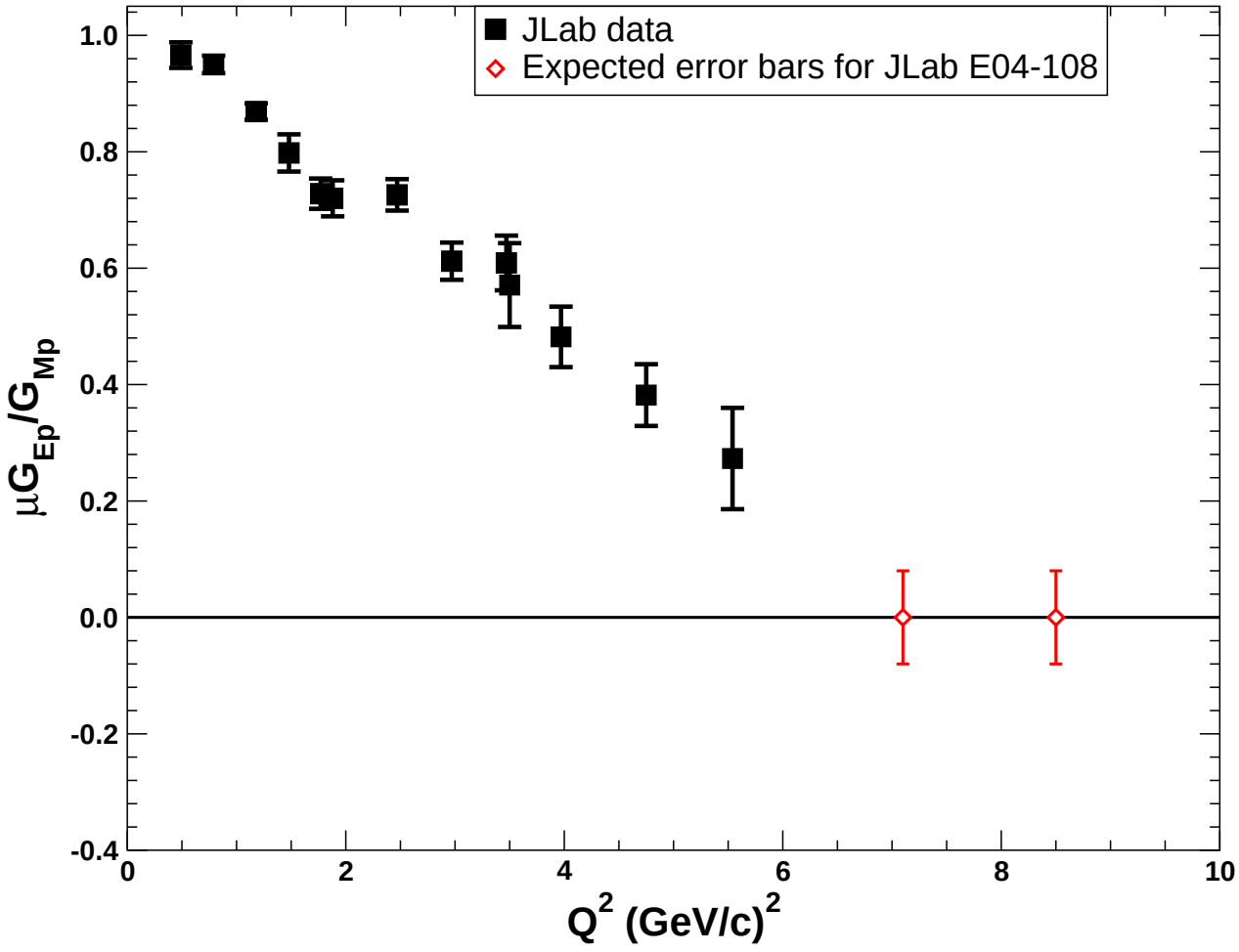
G_{Ep}/G_{Mp} to high Q^2

- This fall take data at $Q^2 = 5.2$, $\chi = 180°$ in HMS.

  Systematic error on χ

- Spring 2008, take data at $Q^2 = 7.1, 8.5$ GeV^2 , beam energy of 5.714 GeV.

  $\Delta G_{Ep}/G_{Mp} = 0.08$



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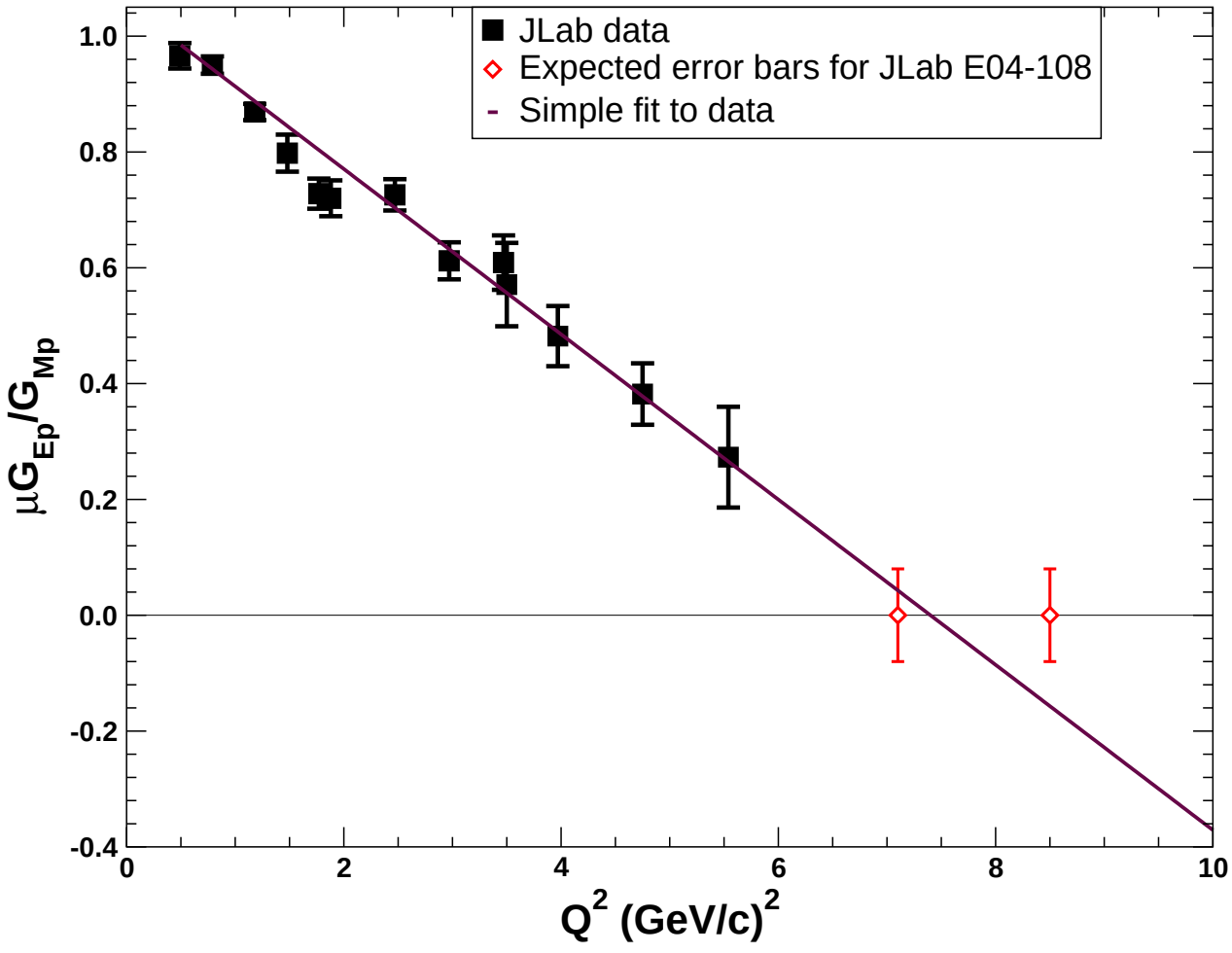

Maybe see zero crossing?

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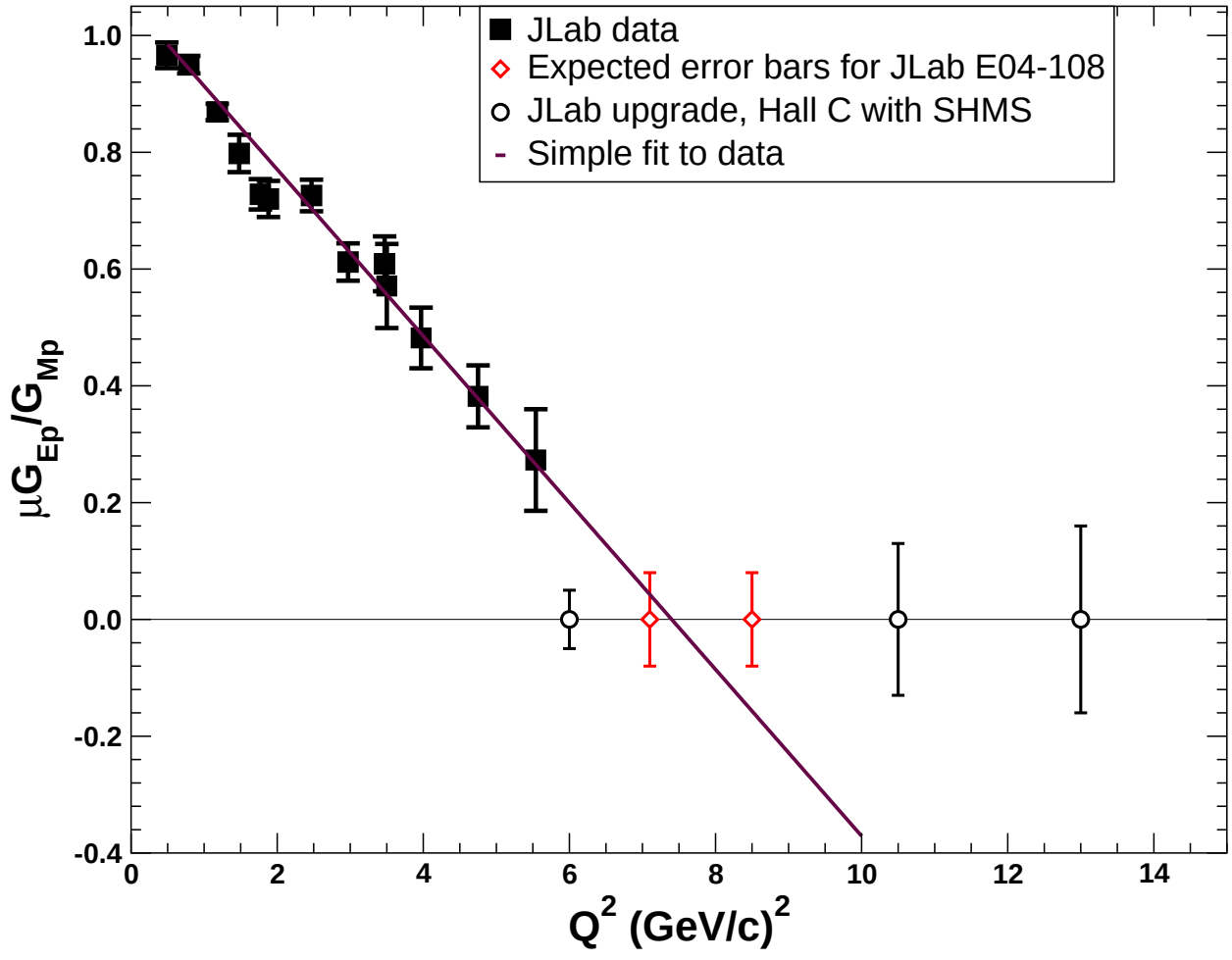
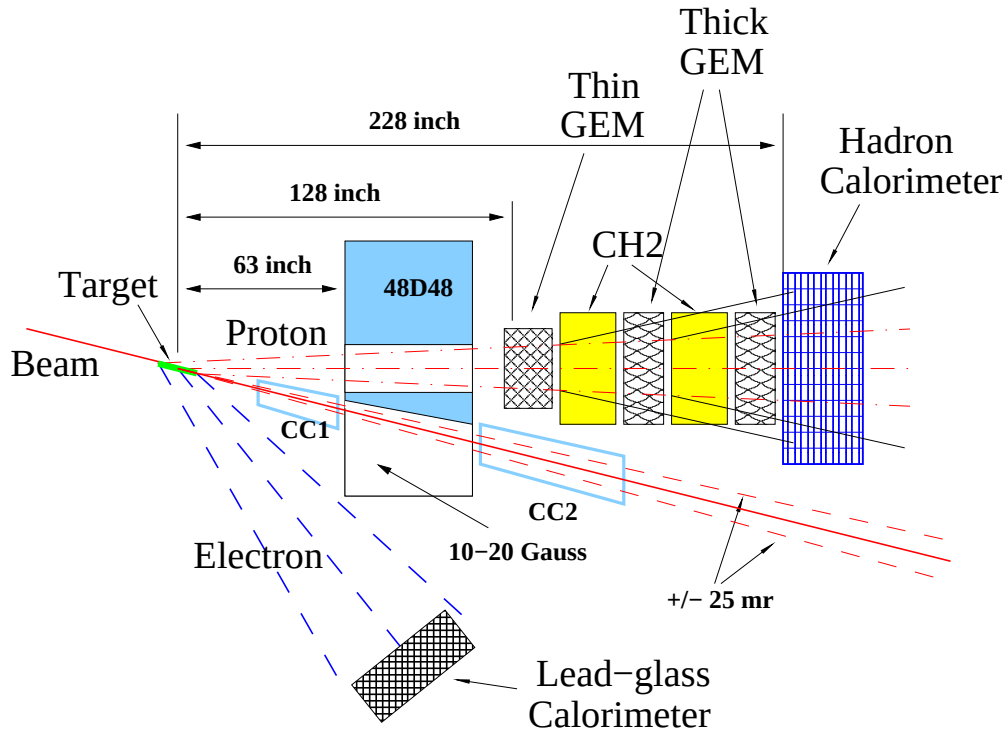
- Sometime 20?? with 12GeV beam, move FPP to SHMS and combined with BigCal extend to Q^2 = 13 GeV^2



Proton G_{Ep}/G_{Mp} in Hall A at 12 GeV

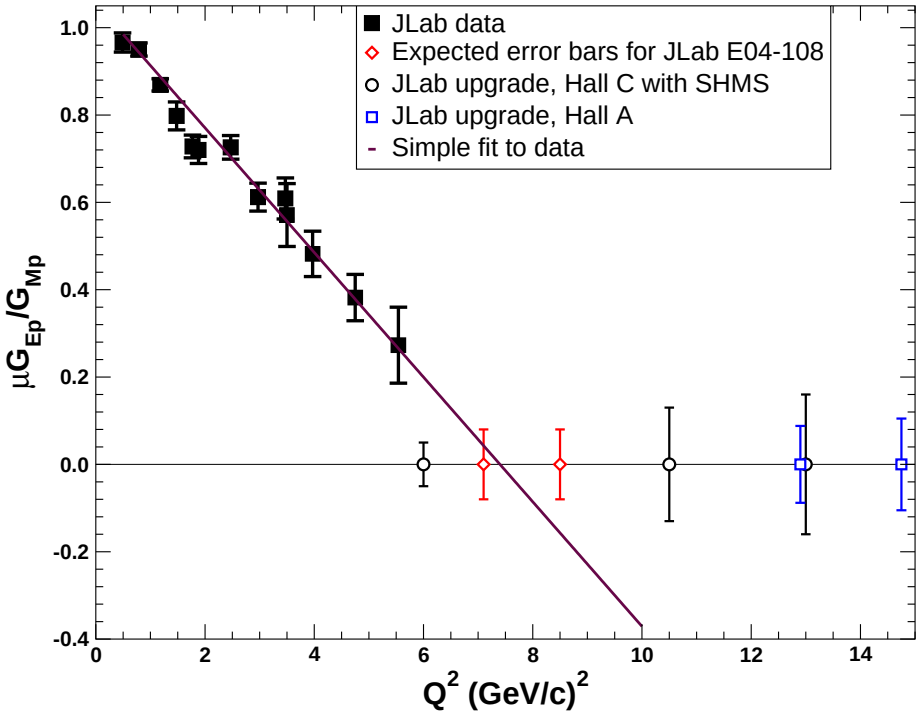
- BigCal at 37° detects electron
- Large $\sigma \approx 35$mr dipole magnet at 14° to detect proton.
- Exit beam pipe thru dipole
- Hadron calorimeter to trigger on > 4 GeV/c protons
- Angular correlation between proton and electron use in trigger.

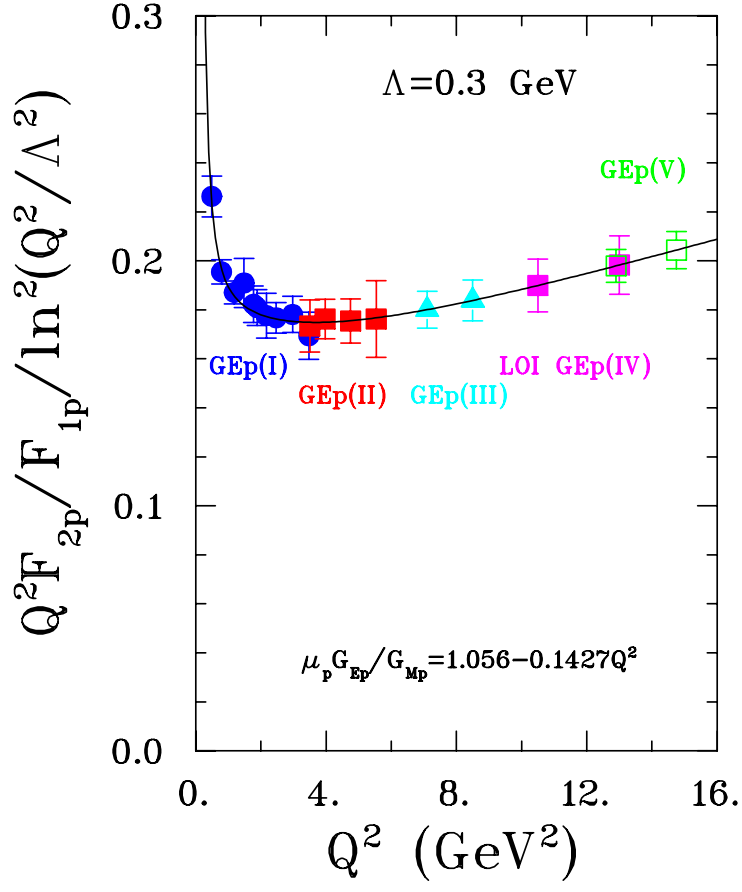
Cover $12.5 < Q^2 < 16$



Spokespeople:C. Perdrisat, L. Pentchev, E. Cisbani, V. Punjabi,B. Wojtsekhowski

Projected results for G_{Ep}/G_{Mp} at 12 GeV





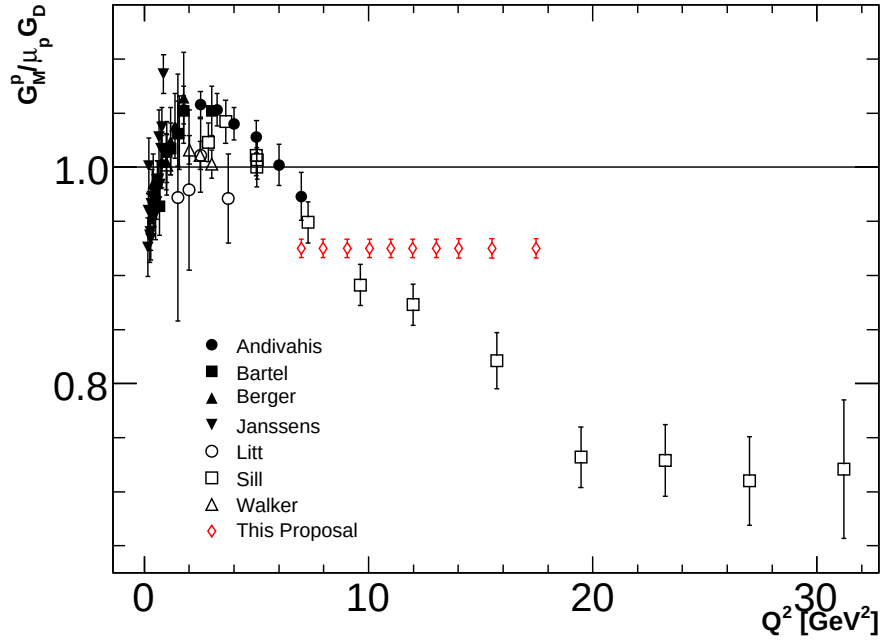
Hall A: 56 days on 40cm LH^2

Hall C: 90 days on 30cm LH^2

Proton G_{Mp} in Hall A at 12 GeV

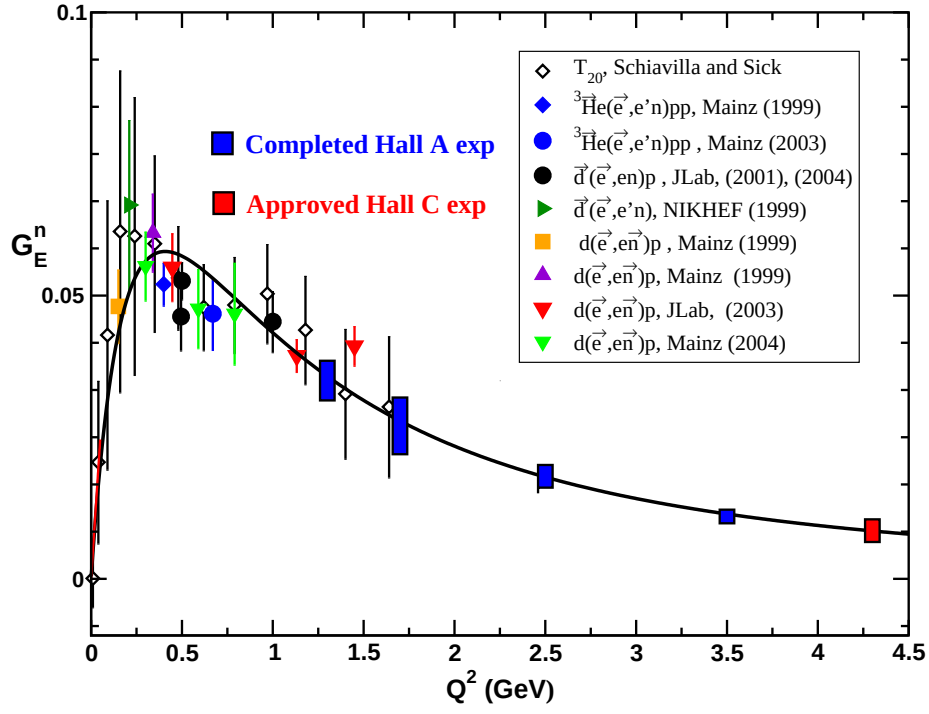
- Only SLAC measurements at large Q^2
- Detect scattered electron in HRS
- 31 days, $\sim \frac{1}{2}$ time at $Q^2 = 17.5$
- Reduce uncertainty in G_{Mp} due to TPE and G_{Ep} contribution to cross section.

$$7 < Q^2 < 17.5$$



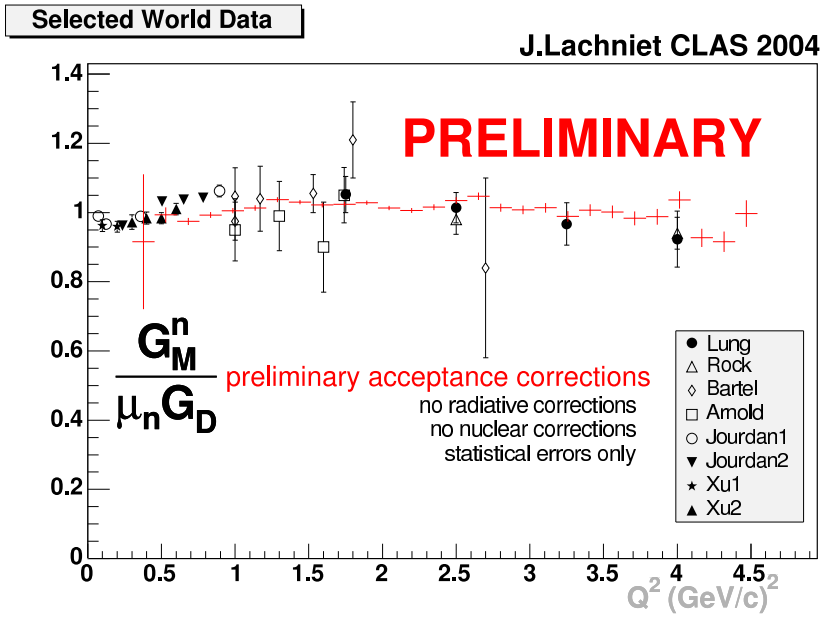
Spokespeople: S. Gilad, B. Moffit, J. Arrington and B. Wojtsekhowski

Neutron Electric Form Factor , G_{En}



- Finished experiment in Hall A at Q^2 = 1.3, 1.7 , 2.5 and 3.5 by $^3\vec{H}e(\vec{e},e'n)$ Ran in Spring 2006 , waiting for fi nished analysis!
- Approved experiment in Hall C Q^2 = 4.3 by $d(\vec{e},e'\,\vec{n})$ waiting to be scheduled!
- With JLab upgrade, both methods can extend to $Q^2 \approx 7$ GeV^2

G_{Mn} measurement in Hall B



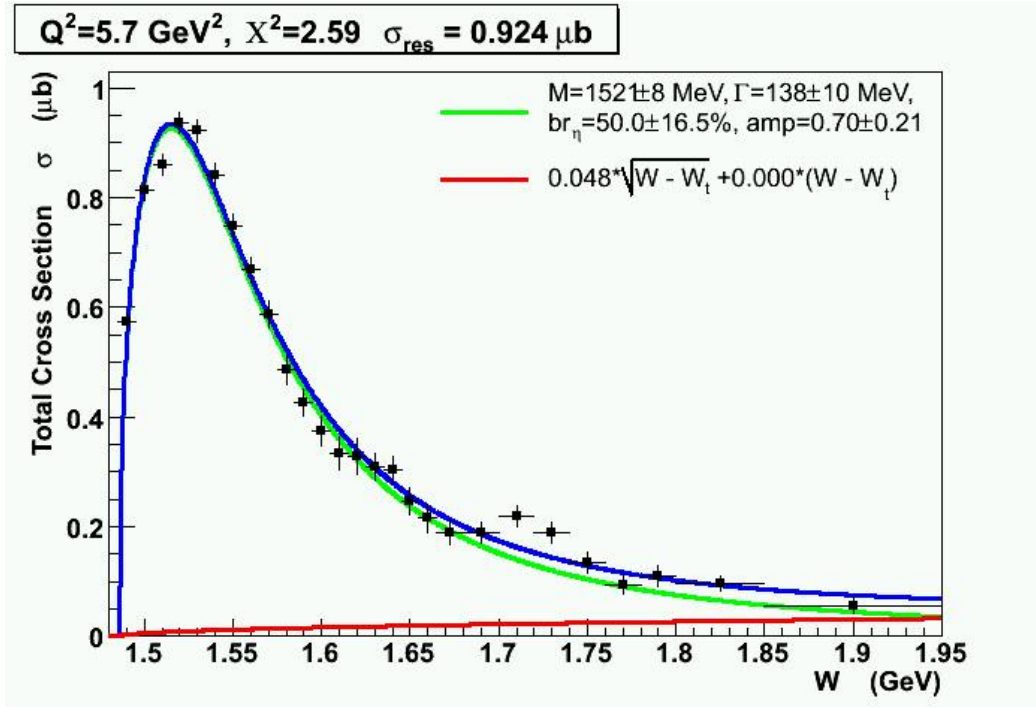
- Extract G_{Mn} → $\frac{\sigma[\mathrm{d(e,e'n)_{QE}}]}{\sigma[\mathrm{d(e,e'p)_{QE}}]}$
- Red points new Hall B data (*Brooks and Lachinet nucl-ex/0504028*)
- Determine neutron efficiency by simultaneous measurement of ^{1}H(e,e$'\pi^+$)n. LH_2 and LD_2 both in beam (5cm apart)
- 12 GeV proposal extends technique to $Q^2 = 14$ in 56 PAC days
  Spokespersons: G. P. Gilfoyle, W. K. Brooks, M. F. Vineyard, K. Hafidi and J. D. Lachniet

S_{11} helicity amplitude in Hall C

- Measure cross sections for
  ^{1}H$(e, e'p)X$ $(X = \pi^\circ, \eta, \omega)$

S_{11} helicity amplitude in Hall C

- Measure cross sections for ^{1}H$(e, e'p)X$ $(X = \pi^\circ, \eta, \omega)$
- Measure η c.m. angular distribution and extract total cross section at Q^2 = 5.7 and 6.9 GeV^2



S_{11} helicity amplitude in Hall C

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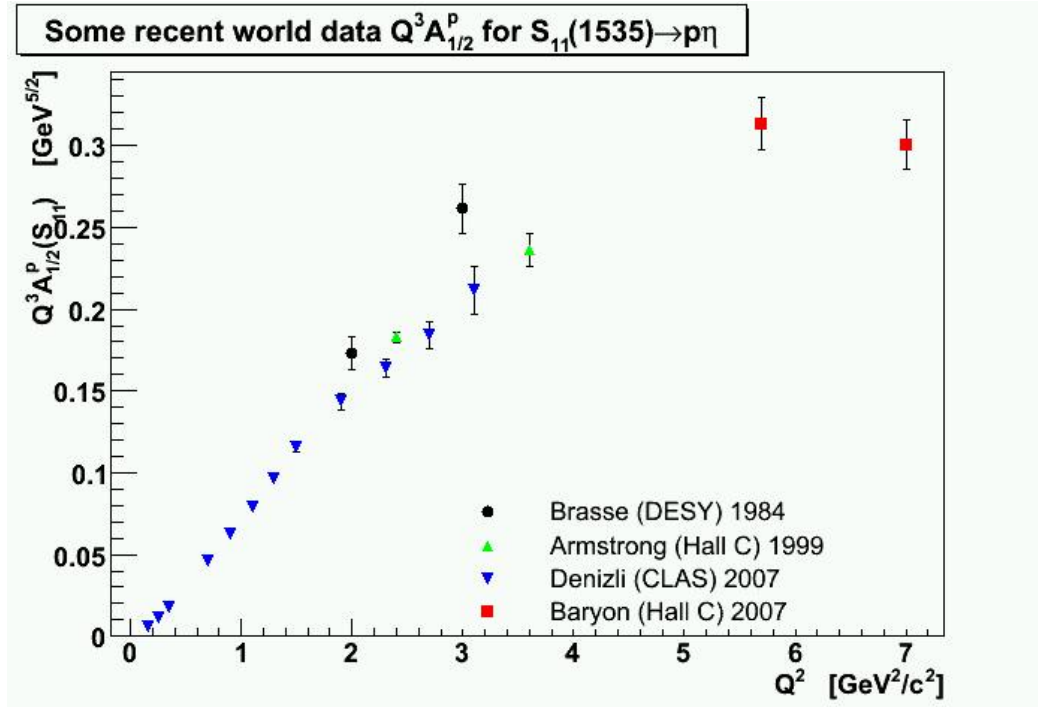
- Measure η c.m. angular distribution and extract total cross section at Q^2 = 5.7 and 6.9 GeV^2
- Convert to helicity amplitude



Summary

- Proton G_E/G_M
  - Spring 2008 in Hall C, $Q^2 \rightarrow$ 8.5 GeV^2.
  - With JLab 12 GeV upgrade $Q^2 \rightarrow$ 15 GeV^2.
- Neutron G_E/G_M
  - Completed Hall A exp, $Q^2 \rightarrow$ 3.5 GeV^2
  - Approved Hall C exp, $Q^2 \rightarrow$ 4.3 GeV^2
  - With JLab 12 GeV upgrade, $Q^2 \rightarrow \approx$ 8 GeV^2
- Neutron G_M
  - Completed Hall B exp, $Q^2 \rightarrow$ 4 GeV^2
  - Possible Hall A exp, $Q^2 \rightarrow$ 8 GeV^2
  - With JLab 12 GeV upgrade, $Q^2 \rightarrow \approx$ 14 GeV^2
- Proton G_M
  - With JLab 12 GeV upgrade, $Q^2 \rightarrow$ 17.5 GeV^2